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(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Hiroshi Naito et al.

Application No.: 10/584,666 Confirmation No.: 4975

Filed: May 29, 2007 Art Unit: 2862

For: MAGNETIC SENSOR AND MANUFACTURING METHOD THEREFOR Examiner: Not Yet Assigned

MATERIALITY OF REFERENCES

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Madam:

The following explanation of relevance is contained in "Background Art" in the specification of related Application Serial No. 11/908,549 (our ref. X2007.0249).

Giant magnetoresistive elements (GMR elements), tunneling magnetoresistive elements (TMR elements) and the like are known as elements usable in a magnetic sensor. These magnetoresistive effect elements are provided with a pinned layer in which the magnetization direction is pinned (bonded) in a predetermined direction and a free layer in which the magnetization direction changes according to an external magnetic field, indicating as an output a resistance value according to the relative relationship between the magnetization direction of the pinned layer and that of the free layer. Magnetic sensors in which the above-described magnetoresistive effect elements are used have been disclosed, for example, in Patent Document 1 and Patent Document 2.

In the magnetic sensors disclosed in Patent Document 1 and Patent Document 2, magnetoresistive effect elements are arranged to be orthogonal to each other in such a way that a

change in magnetic fields of two orthogonal directions (X-axis direction and Y-axis direction) can be respectively detected, and bridge-connected respectively as a group of elements made up of several elements, thereby obtaining outputs of individual elements (change in resistance value) to detect an external magnetic field on a two-dimensional flat surface.

Incidentally, there is a case where in place of a two-dimensional flat surface, a spatial orientation, namely, a three-dimensional orientation is required. In this case, it is necessary to obtain the direction of magnetism in a three-dimensional manner (X-axis direction, Y-axis direction and Z-axis direction) with a high accuracy.

However, since it is impossible to fabricate a three-dimensional magnetic sensor capable of obtaining the direction in a three-dimensional manner on the same substrate, no thin-type three-dimensional magnetic sensor has so far been available.

There has been, therefore, proposed a three-axis magnetic sensor (three-dimensional magnetic sensor) in which two chips are tilted and mounted. In the three-axis magnetic sensor, as given in Fig. 63A illustrating the top surface of the sensor, two chips made up of A chip and B chip which are in a square shape, when viewed from above, are mounted inside a package. Then, these two chips are, as given in Fig. 63B illustrating the side surface, arranged so as to be tilted by an angle of ÿ, X-axis sensors (aÿto d) and y1-axis sensors (e to h) are fabricated on the A chip, and y2-axis sensors (i to l) are fabricated on the B chip. These sensors are constituted respectively with four GMR elements (a to d, e to h, and i to l), and these GMR elements are arranged along the sides of the chips.

Here, as illustrated in Fig. 64A, the GMR elements, a to d, are bridge-connected to constitute the X-axis sensors. Further, as illustrated in Fig. 64B, the GMR elements, e to h, are bridge-connected to constitute the y1-axis sensors. Still further, as illustrated in Fig. 64C, the GMR elements, i to l are bridge-connected to constitute the y2-axis sensors. Then, the GMR elements, a to d, constituting the X-axis sensor are designed to have the sensitivity direction in the X-axis direction, the GMR elements, e to h, constituting the y1-axis sensor are designed to have the

sensitivity direction in the y1-axis direction, and the GMR elements, i to l, constituting the y2-axis sensor are designed to have the sensitivity direction in the y2-axis direction.

Thereby, when a magnetic field is applied to the GMR elements constituting each of the sensors in the direction shown by the arrows in Fig. 63A, the resistance value will decrease proportionally with the magnetic field intensity thereof. In contrast, when a magnetic field is applied in an opposite direction to that shown by the arrows in Fig. 63A, the resistance value will increase proportionally with the magnetic field intensity thereof. Here, as illustrated in Fig. 64A, Fig. 64B and Fig. 64C, each of the GMR elements is bridge-connected to constitute individual sensors. When a predetermined voltage (for example, 3V) is applied between a power source and a ground, Sx is output from the X-axis sensor, Sy1 is output from the y1-axis sensor and Sy2 is output from the y2-axis sensor.

Then, on the basis of the thus obtained outputs, Hx, a component of a magnetic field in the X-axis direction can be obtained by the following formula (1). Similarly, Hy, a component of a magnetic field in the Y-axis direction can be obtained by the following formula (2), and Hz, a component of a magnetic field in the Z-axis direction can be obtained by the following formula (3).

$$Hx = 2kx \ Sx \quad ...(1)$$

$$Hy = ky\ (Sy1 - Sy2)\ /\cos\ddot{y} \quad ...(2)$$

$$Hz = kz\ (Sy1 + Sy2)/\sin\ddot{y} \quad ...(3)$$

Wherein, kx, ky and kx are constants of proportionality and the relationship of kx = ky = kz can be obtained, when each of the sensors is equal in sensitivity.

However, two chips made up of A chip and B chip must be mounted inside the package in the above-described three-axis magnetic sensor, thereby complicating the manufacture of this type of sensor and requiring additional work, which is a problem. There is another problem in that the sensor needs a special package, thereby increasing the price and making it difficult to attain miniaturization.

On the other hand, the applicant of the present invention has already proposed a magnetic sensor in Patent Document 3 in which three or more magnetoresistive elements are arranged on one sheet of a substrate and the magnitude of a magnetic field in a triaxial direction can be determined.

[Patent Document 1] Japanese Patent No. 3498737

[Patent Document 2] Japanese Unexamined Patent Application, First Publication, No. 2002-299728

[Patent Document 3] Japanese Unexamined Patent Application, First Publication, No. 2004-6752

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Respectfully submitted,

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